

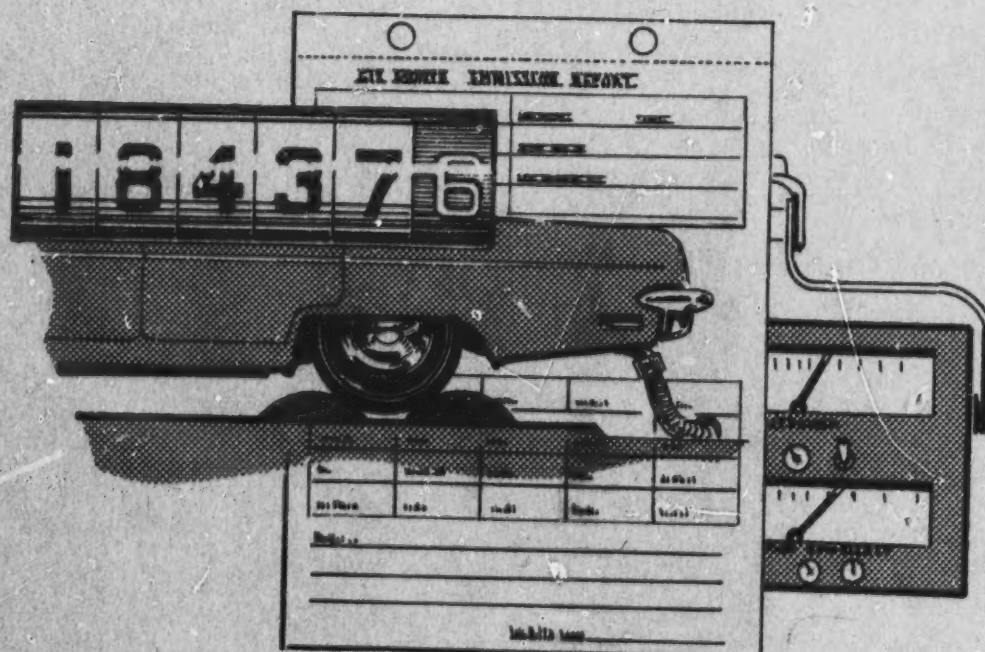
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# RENTAL VEHICLE SURVEILLANCE PROGRAM

March 1968 to January 1970



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**U. S. ENVIRONMENTAL PROTECTION AGENCY**

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**RENTAL VEHICLE  
SURVEILLANCE PROGRAM**

**March 1968 to January 1970**

**Daniel B. Pinkert,  
James M. Marzen, and  
Charles J. Domke  
Bureau of Mobile Source Pollution Control**

**ENVIRONMENTAL PROTECTION AGENCY  
Office of Air Programs  
Research Triangle Park, North Carolina  
November 1971**

The AP series of reports is issued by the Environmental Protection Agency to report the results of scientific and engineering studies, and information of general interest in the field of air pollution. Information presented in this series includes coverage of intramural activities involving air pollution research and control technology and cooperative programs and studies conducted in conjunction with state and local agencies, research institutes, and industrial organizations. Copies of AP reports are available free of charge - as supplies permit - from the Office of Technical Information and Publications, Office of Air Programs, Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

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## ABSTRACT

Exhaust-emission tests were performed on rental vehicles representing 26 vehicle types to ascertain the effectiveness of the Federal exhaust emission standards. Most of the rental vehicles tested had odometer readings of less than 15,000 miles, and had received no engine maintenance other than minor carburetor adjustments. Approximately half the cars with odometer readings in excess of 15,000 miles had received one engine tune-up during their fleet operation.

All vehicles were tested by the standard Federal seven-mode, seven-cycle cold-start test procedure, and by the New Jersey ACID cycle test and the Clayton Key Mode test.

Although exhaust emissions varied considerably among automobiles of different manufacturers, among engines of different types, and among different engines of the same type, most types of engines tested produced emissions at levels below those permitted by Federal standards. More than 80 percent, however, of the Chevrolet 307-CID engines operated for at least 3,500 miles exceeded the Federally established levels. Ford 289- and 302-CID engines also had high emission levels.

Approximately 75 percent of the test vehicles, of types representing about two-thirds of the 1968 and 1969 domestic automobile population, emitted hydrocarbons at levels lower than those permitted by the Federal certification standards, and about 60 percent emitted carbon monoxide at levels lower than those permitted. Projections indicate, however, that a smaller percentage of the vehicles represented in this test program will meet certification standards when they have been operated 50,000 miles.

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## RENTAL VEHICLE SURVEILLANCE PROGRAM, MARCH 1968 TO JANUARY 1970

### INTRODUCTION

The nuisance problem and health hazards of automotive air pollution have received increasing recognition and study over the past decade. The United States Congress passed the Clean Air Act of 1963 to improve, strengthen, and accelerate programs for the prevention and abatement of air pollution. This act, as amended in 1965, authorized the United States Department of Health, Education, and Welfare—under which the national air pollution control program was administered until late 1970—to set national standards for the control of air pollution from new motor vehicles. Standards were issued in early 1966 that established maximum permissible concentrations for hydrocarbon (HC) and carbon monoxide (CO) emissions from automobiles and light-duty trucks sold in the United States, beginning with the 1968 model year. The Federally established maximum allowable concentrations of HC and CO emissions from 1968 and 1969 vehicles, which vary according to the cubic-inch displacement (CID) of the engine,\* are listed below:

| CID        | HC, ppm | CO, % |
|------------|---------|-------|
| 50 to 100  | 410     | 2.3   |
| 100 to 140 | 350     | 2.0   |
| >140       | 275     | 1.5   |

Procedures for testing and certifying prototype vehicles for compliance with Federal exhaust emission standards were drafted and published in the *Federal Register* 31(61), March 30, 1966. These procedures required each manufacturer to build and test a specified number of prototype vehicles that would meet Federal emission standards before Certificates of Conformity were issued to the manufacturer. The procedures did not require that each vehicle

\*For a 4,000-pound car with an automatic transmission, 275 parts per million (ppm) HC is equivalent to 3.5 grams HC per mile, and 1.5 percent CO is equivalent to 36 grams CO per mile. The 1970 standards are 2.2 grams HC per mile and 23 grams CO per mile. The vehicles involved in this test program were not required to meet the 1970 standards, however, inasmuch as they were 1968 and 1969 models.

produced meet the applicable standards. They did require that the average emission values from a sample of two or four emission-data vehicles of each displacement, depending on projected sales volume, be less than the values stated in the standards, when the values had been modified by a deterioration factor obtained from a fleet of four to ten durability-data vehicles, representative of at least 70 percent of the manufacturer's engine displacement and transmission options.

The Federal procedures and standards applicable to 1968- and 1969-model vehicles were similar to those of California, which became effective with 1966 models built for sale in that state. After the 1966 models were introduced for sale, the California authorities, with Federal financial assistance, initiated a program by which to survey the effectiveness of the certified emission-control systems on production, as opposed to prototype, vehicles operated routinely by the ultimate consumer. Periodic reports resulting from this continuing program indicated that emissions from the 1966 models deviated substantially from the standards, especially with increasing mileage. The performance for 1967 and subsequent model-year vehicles was generally better. The results reported by California were obtained from "hot start" tests corrected to "cold start" values by means of average adjustment factors that had been determined experimentally for carbon monoxide and hydrocarbons.

The purpose of the Rental Vehicle Survey was to ascertain the effectiveness of the Federal air pollution regulations by measuring emissions from vehicles driven by the motoring public. Between March 1, 1968, and January 13, 1970, 705 exhaust-emission tests were performed by the Environmental Protection Agency (EPA) at the Los Angeles, California, and Ypsilanti, Michigan, test facilities of EPA's Bureau of Mobile Source Pollution Control on rental vehicles representing 26 different vehicle types. Besides being used to give an indication of the exhaust-emission levels of vehicles in general use, these tests were designed to provide the background information necessary for efficiently planning future surveillance programs for privately owned vehicles.

Vehicles for this program were obtained from the Hertz and Airways rental companies in Los Angeles and from the Hertz and Avis companies in Detroit. Although such rental vehicles may differ from privately owned vehicles with respect to the care with which they are driven, the maintenance they receive, and the type and rate of mileage accumulated, no data are available that define such differences. Lacking data to the contrary, there is no reason to believe that the two groups have different exhaust-emission characteristics.

The original plan for this program was to start with a basic fleet of 138 vehicles, 1968-model year, that would be retested at 3,000- to 4,000-mile intervals. These vehicles were chosen to represent many of the high-production vehicles sold in the United States. Within a short period of time, however, it became apparent that the rental companies could not deliver the vehicles for repetitive testing at the required intervals. In addition, policy changes by the

rental companies resulted in the retention of most rental vehicles for less than 1 year of operation, thereby eliminating any possibility of obtaining large samples of vehicles with more than 20,000 accumulated miles. Hence the surveillance program had to be reorganized to reflect non-repetitive testing of vehicles and the inclusion of low-mileage, 1969-model vehicles in the test fleet.

## TEST VEHICLES AND PROCEDURES

### TEST VEHICLES

The vehicles tested in this program are listed in Table 1. All vehicles, except Volkswagens, were equipped with automatic transmissions, and all vehicles except Cadillacs had engine-modification emission-control systems. The Cadillacs used an air-injection emission-control system. Most engines of a given make and displacement constituted a homogeneous population inasmuch as only one version was tested. Thus, even though Ford Motor Company's 390-CID engine was produced in both two-barrel- and four-barrel-carburetor versions, data were obtained with the two-barrel model only. The 1968 Chevrolet 327-CID engines differed from the same 1969 engines in carburetion and in compression ratio. The difference between 1968 and 1969 versions of all other engines was considered small enough to allow data from the two model years to be combined. Because the 350-CID engines used by General Motors' Buick, Chevrolet, Oldsmobile, and Pontiac Divisions differed in design, a separate analysis was needed for each division's engines.

All test results for a given engine type were combined without regard for body style. Thus, all test results on Ford Motor Company's 302-CID engines were combined even though the test fleet for this engine included a mix of Mercury Cougars, Ford Galaxies, and Ford Mustangs. Similarly, data on Chrysler Corporation's 318-CID engine were obtained by testing both Plymouths and Dodges.

The number of 1968- and 1969-model-year, and 1968- plus 1969-model-year cars tested in each displacement group is given in Table 1 along with estimates of the proportionate use of a particular engine in the total population of domestic cars. These population estimates are described below:

| Column heading                | Meaning                                                                                              |
|-------------------------------|------------------------------------------------------------------------------------------------------|
| % of manufacturer's output    | The percentage of the manufacturer's output that uses the particular engine type.                    |
| % of total vehicle population | The percentage of the total car population under consideration that uses the particular engine type. |

All three rental-car companies received their vehicles from local new-car dealers and not directly from the manufacturers. They did not usually rely on one dealer for all vehicles of a certain model, but received vehicles from many

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Table 1. TEST VEHICLES AND THEIR ESTIMATED DISTRIBUTION IN MANUFACTURER  
AND NATIONAL VEHICLE POPULATIONS

| Manufacturer                   | CID | Carbu-<br>retor<br>barrels | 1968                          |                     |                             | 1969                          |                     |                              | 1968 plus 1969                |                     |                              |
|--------------------------------|-----|----------------------------|-------------------------------|---------------------|-----------------------------|-------------------------------|---------------------|------------------------------|-------------------------------|---------------------|------------------------------|
|                                |     |                            | Number<br>tested <sup>a</sup> | % of<br>mfr. output | % of total<br>U.S. vehicles | Number<br>tested <sup>a</sup> | % of<br>mfr. output | % of total<br>U. S. vehicles | Number<br>tested <sup>a</sup> | % of<br>mfr. output | % of total<br>U. S. vehicles |
| Domestic                       |     |                            |                               |                     |                             |                               |                     |                              |                               |                     |                              |
| American Motors<br>Corporation | 290 | 2                          | 19                            | 28.75               | 0.92                        | 13                            | 29.70               | 0.98                         | 32                            | 29.23               | 0.95                         |
| Total                          | 343 | 2                          | 8                             | 7.19                | 0.23                        | 4                             | 12.73               | 0.42                         | 12                            | 9.85                | 0.32                         |
| Chrysler<br>Corporation        | 225 | 1                          | 27                            | 35.94               | 2.99                        | 17                            | 42.43               | 1.88                         | 44                            | 39.08               | 2.44                         |
| Total                          | 318 | 2                          | 0                             | 15.74               | 6.44                        | 21                            | 10.40               | 6.16                         | 21                            | 13.17               | 6.30                         |
|                                | 383 | 2                          | 40                            | 33.89               | 4.43                        | 9                             | 34.09               | 3.83                         | 49                            | 34.00               | 4.13                         |
|                                | 440 | 4                          | 2                             | 23.32               | 1.82                        | 5                             | 21.20               | 1.80                         | 7                             | 22.29               | 1.81                         |
|                                |     |                            | 0                             | 9.58                |                             | 3                             | 9.96                |                              | 3                             | 9.77                |                              |
| Total                          |     |                            | 42                            | 57.21               |                             | 38                            | 75.65               |                              | 80                            | 79.23               |                              |
| Ford Motor<br>Company          | 200 | 1                          | 0                             | 7.40                | 1.74                        | 11                            | 4.16                | 1.07                         | 11                            | 5.69                | 1.40                         |
|                                | 289 | 2                          | 45                            | 13.87               | 3.26                        | 0                             | 0.00                | 0.00                         | 45                            | 6.62                | 1.63                         |
|                                | 302 | 2                          | 78                            | 32.34               | 7.60                        | 32                            | 32.36               | 8.32                         | 110                           | 32.34               | 7.96                         |
|                                | 351 | 2                          | 0                             | 0.00                | 0.00                        | 13                            | 13.54               | 3.48                         | 13                            | 7.07                | 1.74                         |
|                                | 390 | 2                          | 56                            | 19.96               | 4.69                        | 62                            | 24.54               | 6.31                         | 118                           | 22.35               | 5.50                         |
|                                | 429 | 4                          | 8                             | 3.40                | 0.80                        | 0                             | 4.71                | 1.21                         | 8                             | 4.06                | 1.00                         |
|                                | 460 | 4                          | 1                             | 1.23                | 0.29                        | 4                             | 2.88                | 0.74                         | 5                             | 2.11                | 0.52                         |
|                                | 462 | 4                          | 5                             | 0.89                | 0.21                        | 0                             | 0.00                | 0.00                         | 5                             | 0.41                | 0.10                         |
| Total                          |     |                            | 193                           | 71.69               |                             | 122                           | 77.48               |                              | 315                           | 80.65               |                              |
| General Motors<br>Corporation  | 230 | 1                          | 0                             | 2.39                | 1.30                        | 5                             | 2.65                | 1.40                         | 5                             | 2.52                | 1.35                         |
| Chevrolet                      | 307 | 2                          | 24                            | 17.99               | 9.77                        | 24                            | 6.10                | 3.23                         | 48                            | 12.12               | 6.50                         |

Table 1 (continued). TEST VEHICLES AND THEIR ESTIMATED DISTRIBUTION IN MANUFACTURER AND NATIONAL VEHICLE POPULATIONS

| Manufacturer               | CID | Carbu-<br>retor<br>barrels | 1968                          |                     |                             |                               | 1969                |                             |                               |                     | 1968 plus 1969              |                               |                     |                             |
|----------------------------|-----|----------------------------|-------------------------------|---------------------|-----------------------------|-------------------------------|---------------------|-----------------------------|-------------------------------|---------------------|-----------------------------|-------------------------------|---------------------|-----------------------------|
|                            |     |                            | Number<br>tested <sup>a</sup> | % of<br>mfr. output | % of total<br>U.S. vehicles | Number<br>tested <sup>a</sup> | % of<br>mfr. output | % of total<br>U.S. vehicles | Number<br>tested <sup>a</sup> | % of<br>mfr. output | % of total<br>U.S. vehicles | Number<br>tested <sup>a</sup> | % of<br>mfr. output | % of total<br>U.S. vehicles |
| Domestic                   |     |                            |                               |                     |                             |                               |                     |                             |                               |                     |                             |                               |                     |                             |
| General Motors Corporation |     |                            |                               |                     |                             |                               |                     |                             |                               |                     |                             |                               |                     |                             |
| Chevrolet                  | 327 | 4                          | 48                            | 6.17                | 3.35                        | 0                             | 0.00                | 0.00                        | 0                             | 0.00                | 0.00                        | 48                            | 3.13                | 1.68                        |
| (continued)                | 327 | 2                          | 0                             | 0.00                | 0.00                        | 53                            | 13.83               | 7.32                        | 53                            | 13.83               | 7.32                        | 53                            | 6.83                | 3.66                        |
|                            | 350 | 4                          | 0                             | 0.00                | 0.00                        | 5                             | 6.90                | 3.65                        | 5                             | 6.90                | 3.65                        | 5                             | 3.39                | 1.82                        |
| Pontiac                    | 350 | 2                          | 14                            | 5.75                | 3.12                        | 11                            | 5.16                | 2.73                        | 25                            | 5.16                | 2.73                        | 25                            | 5.45                | 2.92                        |
|                            | 400 | 4                          | 6                             | 6.17                | 3.35                        | 17                            | 4.04                | 2.14                        | 23                            | 4.04                | 2.14                        | 23                            | 5.11                | 2.74                        |
|                            | 428 | 4                          | 0                             | 0.00                | 0.00                        | 4                             | 2.80                | 1.48                        | 4                             | 2.80                | 1.48                        | 4                             | 1.38                | 0.74                        |
| Oldsmobile                 | 350 | 2                          | 0                             | 5.06                | 2.75                        | 4                             | 5.57                | 2.95                        | 4                             | 5.57                | 2.95                        | 4                             | 5.32                | 2.85                        |
|                            | 455 | 4                          | 8                             | 2.87                | 1.56                        | 0                             | 7.14                | 3.78                        | 8                             | 7.14                | 3.78                        | 8                             | 4.98                | 2.67                        |
| Cadillac                   | 472 | 4                          | 8                             | 4.97                | 2.70                        | 0                             | 5.06                | 2.68                        | 8                             | 5.06                | 2.68                        | 8                             | 5.02                | 2.69                        |
| Total                      |     |                            | 108                           | 43.92               |                             | 123                           | 47.05               |                             | 231                           | 55.25               |                             | 231                           | 55.25               |                             |
| Total domestic             |     |                            | 370                           |                     | 63.32                       | 300                           |                     | 67.56                       | 670                           |                     | 65.44                       | 670                           |                     | 65.44                       |
| Foreign                    |     |                            |                               |                     |                             |                               |                     |                             |                               |                     |                             |                               |                     |                             |
| Volkswagen                 | 92  | 1                          | 0                             | -                   | -                           | 35                            | -                   | -                           | 35                            | -                   | -                           | 35                            | -                   | -                           |
| Grand Total                |     |                            | 370                           |                     |                             | 335                           |                     |                             | 705                           |                     |                             | 705                           |                     |                             |

<sup>a</sup>If "Number tested" was zero, production percentage was excluded from totals.

different dealers. All vehicles reportedly received normal dealer make-ready servicing before delivery to the rental-car companies.

Although there were significant differences in the maintenance practices of the three rental-car companies used as vehicle sources for this program, some generalizations can be made about maintenance of the test vehicles. The great majority of vehicles tested in this program with odometer readings of 15,000 miles or less had no engine maintenance other than minor carburetor adjustments performed on them between new-car dealer preparation and the time of test. Approximately half of the cars with greater than 15,000 accumulated miles had their engines tuned once during their fleet operation prior to testing.

### EXHAUST EMISSION STUDY PROCEDURES

All vehicles were tested by the standard Federal seven-mode, seven-cycle cold-start test procedure as described in the *Federal Register* 31(61), II, Paragraphs 85.70-85.83. Following each cold-start test, a New Jersey ACID Cycle test and a Clayton Key Mode test were performed to determine the feasibility of using short exhaust-emission tests as predictors of the Federal seven-mode, cold-start emission test. Data from these short tests are being used in a study of inspection procedures and are not presented in this report.

## RESULTS

Table 2 presents the mean exhaust-emission levels for those 12 displacement groups for which data from 15 or more vehicles were obtained. The table includes the average odometer reading and the averages of the three lowest and of the three highest odometer readings of the vehicles tested; the last two values give the range of mileage for the vehicles tested. The average exhaust emissions are given as arithmetic mean values.

Analysis of the exhaust-emission data for the individual engine-displacement groups revealed that the hydrocarbon and carbon monoxide concentrations were lognormally rather than normally distributed; that is, the logarithms of the values closely approximated a normal distribution. The geometric mean is the value corresponding to the average of the logarithms; the HC and CO geometric mean concentrations are listed in Table 2. (For a group of values whose logarithms are normally distributed, half of the values will be above and half below the geometric mean. The probability is 95 percent that the true value of the geometric mean is between the lower confidence limit (LCL) and the upper confidence limit (UCL).)

Table 3 presents the mean exhaust-emission levels for those vehicles that had accumulated at least 3,500 miles. Although tests were conducted on a number of vehicles with lower mileage to develop some background-emissions information on engines not fully broken in, data from these tests were eliminated from this analysis for two reasons. First, emissions produced by vehicles with low mileage—before piston rings have seated and equilibrium combustion chamber deposits have accumulated—were suspected to be erratic and to change rapidly as mileage was accumulated; thus they could not be used to develop real-life data that could be compared with the 4,000- to 50,000-mile values, modified by deterioration factors, that were determined from certification prototypes. Second, some displacement groups contained vehicles with low mileage and others did not, and the elimination of the low-mileage tests tended to equalize the average odometer readings for each group, making comparisons of emission data among groups more meaningful.

In general, the average HC emissions were somewhat higher for the groups of cars with more than 3,500 miles than for the corresponding groups containing all cars tested, regardless of odometer readings. The differences in average CO values were slight.

Table 4 presents the percentage of cars in each displacement group, from which 15 or more cars were tested, that produced HC and/or CO emissions in excess of the limits prescribed by Federal standards. Results obtained after eliminating data from cars with fewer than 3,500 miles are also presented.

Table 2. MEAN EMISSION CONCENTRATIONS FOR ALL DISPLACEMENT GROUPS WITH 15 OR MORE TESTS

| Manufacturer                | CID | Number tested | Odometer readings |                      |                      | Hydrocarbon emissions, ppm |                |                  | Carbon monoxide emissions, % |                 |                |                  |                  |
|-----------------------------|-----|---------------|-------------------|----------------------|----------------------|----------------------------|----------------|------------------|------------------------------|-----------------|----------------|------------------|------------------|
|                             |     |               | Average           | Average of minimum 3 | Average of maximum 3 | Arithmetic mean            | Geometric mean | LCL <sup>a</sup> | UCL <sup>b</sup>             | Arithmetic mean | Geometric mean | LCL <sup>a</sup> | UCL <sup>b</sup> |
| American Motors Corporation | 290 | 32            | 5,133             | 263                  | 10,709               | 213                        | 211            | 199              | 223                          | 1.13            | 1.06           | 0.91             | 1.23             |
| Chrysler Corporation        | 225 | 21            | 13,568            | 4,272                | 24,086               | 215                        | 212            | 195              | 229                          | 1.70            | 1.56           | 1.29             | 1.89             |
|                             | 318 | 49            | 4,991             | 34                   | 14,265               | 230                        | 226            | 214              | 239                          | 1.09            | 1.01           | 0.91             | 1.13             |
| Ford Motor Company          | 289 | 45            | 10,994            | 4,050                | 21,397               | 320                        | 304            | 279              | 332                          | 1.39            | 1.22           | 1.06             | 1.41             |
|                             | 302 | 110           | 8,953             | 940                  | 21,821               | 305                        | 294            | 279              | 308                          | 1.19            | 1.04           | 0.95             | 1.14             |
| General Motors Corporation  | 390 | 118           | 3,044             | 34                   | 24,199               | 228                        | 213            | 201              | 226                          | 1.11            | 0.89           | 0.80             | 0.99             |
|                             |     |               |                   |                      |                      |                            |                |                  |                              |                 |                |                  |                  |
| Chevrolet 1968              | 307 | 48            | 9,548             | 1,088                | 20,311               | 325                        | 299            | 268              | 334                          | 1.52            | 1.40           | 1.23             | 1.60             |
|                             | 327 | 48            | 16,960            | 6,525                | 25,991               | 289                        | 282            | 264              | 300                          | 1.76            | 1.66           | 1.49             | 1.84             |
| Chevrolet 1969              | 327 | 53            | 5,611             | 44                   | 22,391               | 231                        | 226            | 213              | 239                          | 1.56            | 1.46           | 1.32             | 1.62             |
|                             |     |               |                   |                      |                      |                            |                |                  |                              |                 |                |                  |                  |
| Pontiac                     | 350 | 25            | 9,631             | 486                  | 17,187               | 219                        | 215            | 198              | 233                          | 1.55            | 1.42           | 1.17             | 1.72             |
|                             | 400 | 23            | 6,492             | 1,550                | 12,042               | 176                        | 173            | 159              | 188                          | 1.46            | 1.40           | 1.23             | 1.59             |
| Volkswagen                  | 92  | 35            | 9,914             | 53                   | 18,364               | 372                        | 359            | 328              | 393                          | 2.14            | 1.97           | 1.74             | 2.23             |
|                             |     |               |                   |                      |                      |                            |                |                  |                              |                 |                |                  |                  |

LCL = Lower confidence limit of 95 percent confidence interval

<sup>a</sup>LCL = Lower confidence limit of 95-percent confidence interval on geometric mean.<sup>b</sup>UCL = Upper confidence limit of 95-percent confidence interval on geometric mean.

# Results

Table 3. MEAN EMISSION CONCENTRATIONS FOR ALL DISPLACEMENT GROUPS WITH 15 OR MORE TESTS  
(Tests on vehicles with less than 3,500 miles eliminated)

| Manufacturer                | CID | Number tested | Odometer readings |                      |                      | Hydrocarbon emissions, ppm |                |                  |                  | Carbon monoxide emissions, % |                |                  |                  |
|-----------------------------|-----|---------------|-------------------|----------------------|----------------------|----------------------------|----------------|------------------|------------------|------------------------------|----------------|------------------|------------------|
|                             |     |               | Average           | Average of minimum 3 | Average of maximum 3 | Arithmetic mean            | Geometric mean | LCL <sup>a</sup> | UCL <sup>b</sup> | Arithmetic mean              | Geometric mean | LCL <sup>a</sup> | UCL <sup>b</sup> |
| American Motors Corporation | 290 | 24            | 6,157             | 3,690                | 10,709               | 218                        | 216            | 206              | 228              | 1.12                         | 1.05           | 0.88             | 1.26             |
| Chrysler Corporation        | 225 | 20            | 14,178            | 6,739                | 24,086               | 215                        | 212            | 195              | 230              | 1.71                         | 1.56           | 1.28             | 1.91             |
|                             | 318 | 28            | 8,125             | 3,661                | 14,265               | 240                        | 234            | 214              | 256              | 1.18                         | 1.06           | 0.89             | 1.26             |
| Ford Motor Company          | 289 | 44            | 11,191            | 4,902                | 21,397               | 323                        | 308            | 283              | 336              | 1.40                         | 1.23           | 1.06             | 1.42             |
|                             | 302 | 95            | 10,038            | 3,827                | 21,821               | 314                        | 303            | 288              | 318              | 1.23                         | 1.08           | 0.98             | 1.19             |
|                             | 390 | 72            | 12,461            | 4,384                | 24,199               | 252                        | 232            | 212              | 253              | 1.36                         | 1.04           | 0.89             | 1.22             |
| General Motors Corporation  |     |               |                   |                      |                      |                            |                |                  |                  |                              |                |                  |                  |
| Chevrolet                   | 307 | 36            | 12,040            | 4,773                | 20,311               | 355                        | 328            | 288              | 372              | 1.56                         | 1.43           | 1.22             | 1.68             |
|                             | 327 | 48            | 16,960            | 6,525                | 25,991               | 289                        | 282            | 264              | 300              | 1.76                         | 1.66           | 1.49             | 1.84             |
|                             | 327 | 32            | 8,354             | 3,817                | 22,391               | 251                        | 248            | 233              | 263              | 1.59                         | 1.50           | 1.32             | 1.70             |
| Pontiac                     | 350 | 21            | 11,236            | 5,536                | 17,187               | 215                        | 211            | 193              | 230              | 1.61                         | 1.50           | 1.25             | 1.80             |
|                             | 400 | 21            | 7,061             | 3,703                | 12,042               | 177                        | 173            | 158              | 190              | 1.50                         | 1.44           | 1.26             | 1.64             |
| Volkswagen                  | 92  | 30            | 11,537            | 5,531                | 18,364               | 391                        | 380            | 349              | 414              | 2.17                         | 1.97           | 1.71             | 2.28             |

<sup>a</sup>LCL = lower confidence limit of 95 percent confidence interval on geometric mean.

<sup>b</sup>UCL = Upper confidence limit of 95 percent confidence interval on geometric mean.

Table 4. PERCENTAGE OF CARS WITH EMISSIONS EXCEEDING STANDARDS  
(For all displacement groups with 15 or more tests)

| Manufacturer                | CID | Tests on all cars |                          |                                      |    |      | Tests on cars with more than 3,500 miles |                          |                                      |    |      |
|-----------------------------|-----|-------------------|--------------------------|--------------------------------------|----|------|------------------------------------------|--------------------------|--------------------------------------|----|------|
|                             |     | Number tested     | Average odometer reading | Cars with emissions over standard, % |    |      | Number tested                            | Average odometer reading | Cars with emissions over standard, % |    |      |
|                             |     |                   |                          | HC                                   | CO | Both |                                          |                          | HC                                   | CO | Both |
| American Motors Corporation | 290 | 32                | 5,133                    | 0                                    | 13 | 0    | 24                                       | 6,157                    | 0                                    | 8  | 0    |
| Chrysler Corporation        | 225 | 21                | 13,568                   | 14                                   | 48 | 14   | 20                                       | 14,178                   | 15                                   | 45 | 15   |
|                             | 318 | 49                | 4,991                    | 12                                   | 10 | 4    | 28                                       | 8,125                    | 18                                   | 14 | 7    |
| Ford Motor Company          | 289 | 45                | 10,994                   | 62                                   | 22 | 20   | 44                                       | 11,191                   | 62                                   | 23 | 20   |
|                             | 302 | 110               | 8,953                    | 58                                   | 19 | 19   | 95                                       | 10,038                   | 63                                   | 20 | 20   |
|                             | 390 | 118               | 3,044                    | 16                                   | 15 | 8    | 72                                       | 12,461                   | 25                                   | 24 | 13   |
| General Motors Corporation  |     |                   |                          |                                      |    |      |                                          |                          |                                      |    |      |
| Chevrolet                   | 307 | 48                | 9,548                    | 60                                   | 54 | 42   | 36                                       | 12,040                   | 75                                   | 56 | 47   |
| 1968                        | 327 | 48                | 16,960                   | 42                                   | 58 | 29   | 48                                       | 16,960                   | 42                                   | 58 | 29   |
| 1969                        | 327 | 53                | 5,611                    | 10                                   | 47 | 4    | 32                                       | 8,354                    | 16                                   | 44 | 6    |
| Pontiac                     | 350 | 25                | 9,631                    | 16                                   | 56 | 8    | 21                                       | 11,236                   | 14                                   | 62 | 10   |
|                             | 400 | 23                | 6,492                    | 0                                    | 48 | 0    | 21                                       | 7,061                    | 0                                    | 52 | 0    |
| Volkswagen                  | 92  | 35                | 9,914                    | 31                                   | 23 | 9    | 30                                       | 11,537                   | 37                                   | 20 | 10   |

The average Ford 289- and 302-CID engines and the average Chevrolet 307-CID engines had HC emissions considerably in excess of Federal standards. The average 1968 Chevrolet 327-CID engine had HC emissions slightly higher than the standards. Of the remaining displacement groups (with 15 or more test vehicles), all had average HC values less than the limits imposed by the Federal standards.

Although several of the displacement groups had average CO emissions slightly higher than the standards, none of the averages was significantly greater than the standard.

Results for the 14 engine-displacement groups represented by fewer than 15 test vehicles are presented in Tables 5 through 7. A sample smaller than 15 was considered too small to allow meaningful statements about average emissions for the displacement group because the effect of random fluctuations on data from such a small sample could be relatively large.

Estimates of the exhaust emissions of the population of domestic vehicles were made by combining exhaust-emission data and the estimated production percentages shown in Table 1. Foreign vehicles were excluded because only Volkswagen data were obtained and the Volkswagen, because of its small engine size, was subject to emission standards that were different from those applicable to domestic vehicles. The distribution of HC and CO emissions is shown respectively in Figures 1 and 2. Similar plots were made after data obtained from vehicles with fewer than 3,500 miles were eliminated, but these are not presented because they were almost identical in appearance to Figures 1 and 2. The data may be summarized as shown in Table 8.

As these data show, more than half of the vehicle population represented by the test sample had exhaust emissions, at the mileage levels of the vehicles sampled, below the limits prescribed in the Federal standards.

An attempt was made to estimate the change in emission levels with mileage for each displacement group. The sample, however, was not well suited to this type of analysis because most of the cars had accumulated relatively few miles, ranging from a low of 29 to a high of 27,493, with an average of only 7,708 miles. Past experience indicates, however, that vehicle emissions increase with mileage accumulation. It is reasonable to conclude, therefore, that although this study provides no basis for predicting emission levels at 50,000 miles, many of the vehicles will have higher emission levels when they have been driven 50,000 miles.

Table 5. MEAN EMISSION CONCENTRATIONS FOR ALL DISPLACEMENT GROUPS WITH LESS THAN 15 TESTS

| Manufacturer                | CID | Number tested | Odometer readings |                      |                      | Hydrocarbon emissions, ppm |                |                  | Carbon monoxide emissions, % |                |                                   |
|-----------------------------|-----|---------------|-------------------|----------------------|----------------------|----------------------------|----------------|------------------|------------------------------|----------------|-----------------------------------|
|                             |     |               | Average           | Average of minimum 2 | Average of maximum 2 | Arithmetic mean            | Geometric mean | LCL <sup>a</sup> | Arithmetic mean              | Geometric mean | LCL <sup>a</sup> UCL <sup>b</sup> |
| American Motors Corporation | 343 | 12            | 3,846             | 1,593                | 6,130                | 203                        | 201            | 184              | 0.94                         | 0.90           | 0.74 1.10                         |
| Chrysler Corporation        | 383 | 7             | 3,050             | 478                  | 5,096                | 212                        | 207            | 167              | 1.17                         | 1.08           | 0.73 1.61                         |
|                             | 440 | 3             | 3,883             | 2,873                | 4,704                | 217                        | 214            | 135              | 0.89                         | 0.88           | 0.44 1.76                         |
| Ford Motor Company          | 200 | 11            | 741               | 32                   | 3,156                | 212                        | 211            | 195              | 1.07                         | 1.05           | 0.90 1.35                         |
|                             | 351 | 13            | 4,397             | 1,275                | 6,904                | 210                        | 209            | 195              | 0.83                         | 0.74           | 0.54 1.00                         |
|                             | 429 | 8             | 11,013            | 6,129                | 15,806               | 215                        | 196            | 139              | 1.76                         | 1.60           | 1.08 2.36                         |
|                             | 460 | 5             | 4,221             | 3,735                | 4,813                | 186                        | 178            | 116              | 1.42                         | 1.28           | 0.69 2.36                         |
| General Motors Corporation  | 462 | 5             | 11,910            | 6,936                | 15,757               | 203                        | 197            | 140              | 1.51                         | 1.50           | 1.23 1.83                         |
|                             |     |               |                   |                      |                      |                            |                |                  |                              |                |                                   |
| Chevrolet                   | 230 | 5             | 5,060             | 3,368                | 7,303                | 185                        | 183            | 149              | 1.37                         | 1.32           | 0.88 1.98                         |
|                             | 350 | 5             | 12,704            | 3,827                | 21,628               | 214                        | 212            | 182              | 1.95                         | 1.93           | 1.51 2.46                         |
| Pontiac                     | 428 | 4             | 5,089             | 2,328                | 7,852                | 324                        | 319            | 228              | 2.72                         | 2.68           | 1.93 3.73                         |
| Oldsmobile                  | 350 | 4             | 4,155             | 2,377                | 5,934                | 187                        | 186            | 168              | 2.34                         | 2.31           | 1.66 3.23                         |
|                             | 455 | 8             | 13,255            | 10,208               | 16,434               | 138                        | 137            | 126              | 2.09                         | 2.07           | 1.76 3.10                         |
| Cadillac                    | 472 | 8             | 6,300             | 652                  | 11,494               | 146                        | 145            | 130              | 1.08                         | 1.08           | 0.98 1.19                         |

<sup>a</sup>LCL : Lower confidence limit of 95-percent confidence interval on geometric mean.<sup>b</sup>UCL : Upper confidence limit of 95-percent confidence interval on geometric mean.

Table 6. MEAN EMISSION CONCENTRATIONS FOR ALL DISPLACEMENT GROUPS WITH LESS THAN 15 TESTS  
(Tests on vehicles with less than 3,500 miles eliminated)

| Manufacturer                | CID | Number tested | Odometer readings |                      |                      | Hydrocarbon emissions, ppm |                |                  |                  | Carbon monoxide emissions, % |                |                  |                  |
|-----------------------------|-----|---------------|-------------------|----------------------|----------------------|----------------------------|----------------|------------------|------------------|------------------------------|----------------|------------------|------------------|
|                             |     |               | Average           | Average of minimum 2 | Average of maximum 2 | Arithmetic mean            | Geometric mean | LCL <sup>a</sup> | UCL <sup>b</sup> | Arithmetic mean              | Geometric mean | LCL <sup>a</sup> | UCL <sup>b</sup> |
| American Motors Corporation | 343 | 8             | 4,827             | 4,039                | 6,130                | 215                        | 214            | 192              | 238              | 1.03                         | 0.99           | 0.76             | 1.29             |
| Chrysler Corporation        | 383 | 4             | 4,360             | 3,625                | 5,096                | 224                        | 222            | 171              | 287              | 1.15                         | 1.07           | 0.56             | 2.07             |
|                             | 440 | 2             | 4,704             | 4,704                | 4,704                | 210                        | 206            | 22               | 1,928            | 0.94                         | 0.92           | 0.03             | 27.90            |
| Ford Motor Company          | 200 | 1             | 4,903             | 4,903                | 4,903                | 267                        | 267            | —                | —                | 1.10                         | 1.10           | —                | —                |
|                             | 351 | 9             | 5,627             | 4,085                | 6,904                | 213                        | 212            | 194              | 231              | 0.88                         | 0.83           | 0.64             | 1.09             |
|                             | 429 | 8             | 11,013            | 6,129                | 15,806               | 215                        | 196            | 139              | 276              | 1.76                         | 1.60           | 1.08             | 2.36             |
|                             | 460 | 5             | 4,221             | 3,735                | 4,813                | 186                        | 178            | 116              | 273              | 1.42                         | 1.28           | 0.69             | 2.36             |
| General Motors Corporation  | 462 | 4             | 14,169            | 12,582               | 15,757               | 201                        | 194            | 117              | 322              | 1.52                         | 1.50           | 1.12             | 2.02             |
|                             | 230 | 4             | 5,628             | 3,954                | 7,303                | 187                        | 184            | 136              | 249              | 1.42                         | 1.35           | 0.75             | 2.44             |
|                             | 350 | 4             | 15,124            | 8,622                | 21,628               | 221                        | 220            | 183              | 263              | 1.97                         | 1.93           | 1.35             | 2.78             |
|                             | 428 | 3             | 6,498             | 5,700                | 7,852                | 355                        | 355            | 327              | 385              | 2.96                         | 2.96           | 2.40             | 3.65             |
| Oldsmobile                  | 350 | 3             | 5,323             | 4,135                | 5,934                | 182                        | 182            | 161              | 205              | 2.20                         | 2.17           | 1.31             | 3.60             |
|                             | 455 | 8             | 13,255            | 10,208               | 16,234               | 138                        | 137            | 126              | 149              | 2.09                         | 2.07           | 1.76             | 2.43             |
| Cadillac                    | 472 | 6             | 8,183             | 4,974                | 11,494               | 155                        | 154            | 140              | 170              | 1.09                         | 1.09           | 0.95             | 1.25             |

<sup>a</sup>LCL : Lower confidence limit of 95-percent confidence interval on geometric mean.

<sup>b</sup>UCL : Upper confidence limit of 95-percent confidence interval on geometric mean.

Table 7. PERCENTAGE OF CARS WITH EMISSIONS EXCEEDING STANDARDS  
(For all displacement groups with less than 15 tests)

| Manufacturer                | CID | All tests     |                          |                                      |     |      | Tests on cars with more than 3,500 miles |                          |                                      |     |     |      |
|-----------------------------|-----|---------------|--------------------------|--------------------------------------|-----|------|------------------------------------------|--------------------------|--------------------------------------|-----|-----|------|
|                             |     | Number tested | Average odometer reading | Cars with emissions over standard, % |     |      | Number tested                            | Average odometer reading | Cars with emissions over standard, % |     |     |      |
|                             |     |               |                          | HC                                   | CO  | Both |                                          |                          | Either                               | HC  | CO  | Both |
| American Motors Corporation | 343 | 12            | 3,846                    | 0                                    | 0   | 0    | 8                                        | 4,827                    | 0                                    | 0   | 0   | 0    |
| Chrysler Corporation        | 383 | 7             | 3,050                    | 14                                   | 28  | 0    | 4                                        | 4,360                    | 25                                   | 25  | 0   | 50   |
|                             | 440 | 3             | 3,883                    | 0                                    | 0   | 0    | 2                                        | 4,704                    | 0                                    | 0   | 0   | 0    |
| Ford Motor Company          | 200 | 11            | 741                      | 0                                    | 0   | 0    | 1                                        | 4,903                    | 0                                    | 0   | 0   | 0    |
|                             | 351 | 13            | 4,397                    | 0                                    | 8   | 0    | 9                                        | 5,627                    | 0                                    | 11  | 0   | 11   |
|                             | 429 | 8             | 11,013                   | 13                                   | 63  | 13   | 8                                        | 11,013                   | 13                                   | 63  | 13  | 63   |
|                             | 460 | 5             | 4,221                    | 0                                    | 40  | 0    | 5                                        | 4,221                    | 0                                    | 40  | 0   | 40   |
|                             | 462 | 5             | 11,910                   | 0                                    | 40  | 0    | 4                                        | 14,169                   | 0                                    | 50  | 0   | 50   |
| General Motors Corporation  |     |               |                          |                                      |     |      |                                          |                          |                                      |     |     |      |
| Chevrolet                   | 230 | 5             | 5,060                    | 0                                    | 20  | 0    | 4                                        | 5,628                    | 0                                    | 25  | 0   | 25   |
|                             | 350 | 5             | 12,704                   | 0                                    | 100 | 0    | 4                                        | 15,124                   | 0                                    | 100 | 0   | 100  |
| Pontiac                     | 428 | 4             | 5,089                    | 76                                   | 100 | 76   | 3                                        | 6,438                    | 100                                  | 100 | 100 | 100  |
| Oldsmobile                  | 350 | 4             | 4,155                    | 0                                    | 100 | 0    | 3                                        | 5,323                    | 0                                    | 100 | 0   | 100  |
|                             | 455 | 8             | 13,255                   | 0                                    | 100 | 0    | 8                                        | 13,255                   | 0                                    | 100 | 0   | 100  |
| Cadillac                    | 472 | 8             | 6,300                    | 0                                    | 0   | 0    | 6                                        | 8,183                    | 0                                    | 0   | 0   | 0    |

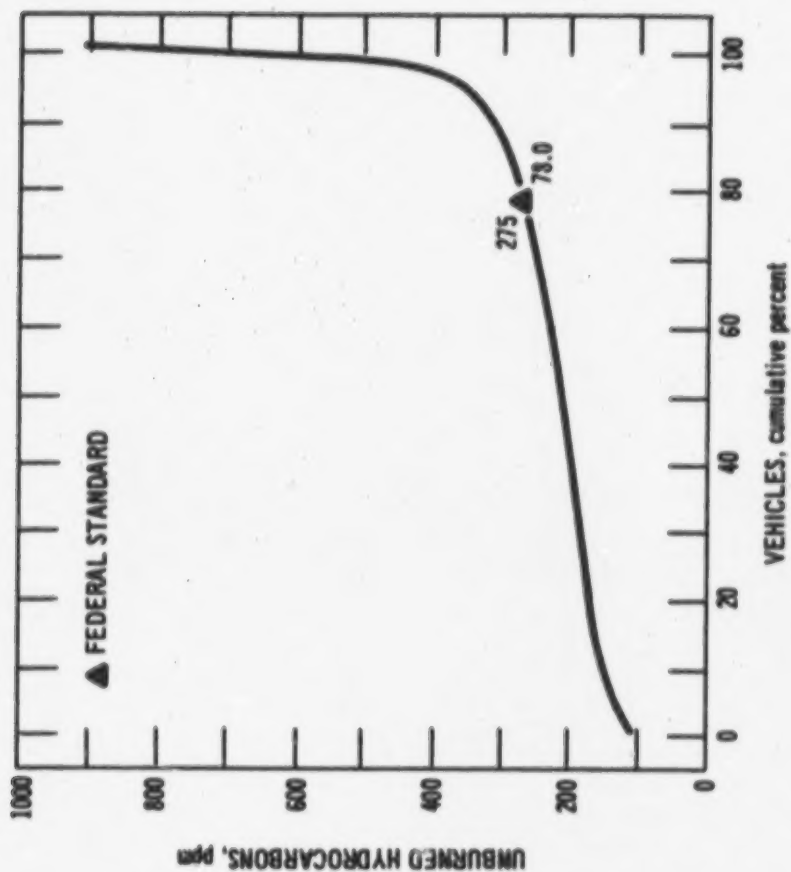


Figure 1. Unburned hydrocarbon emissions versus cumulative percentage of domestic cars represented by test sample. (Test sample represents 65 percent of combined 1968 plus 1969 production, with percentages weighted according to production.)

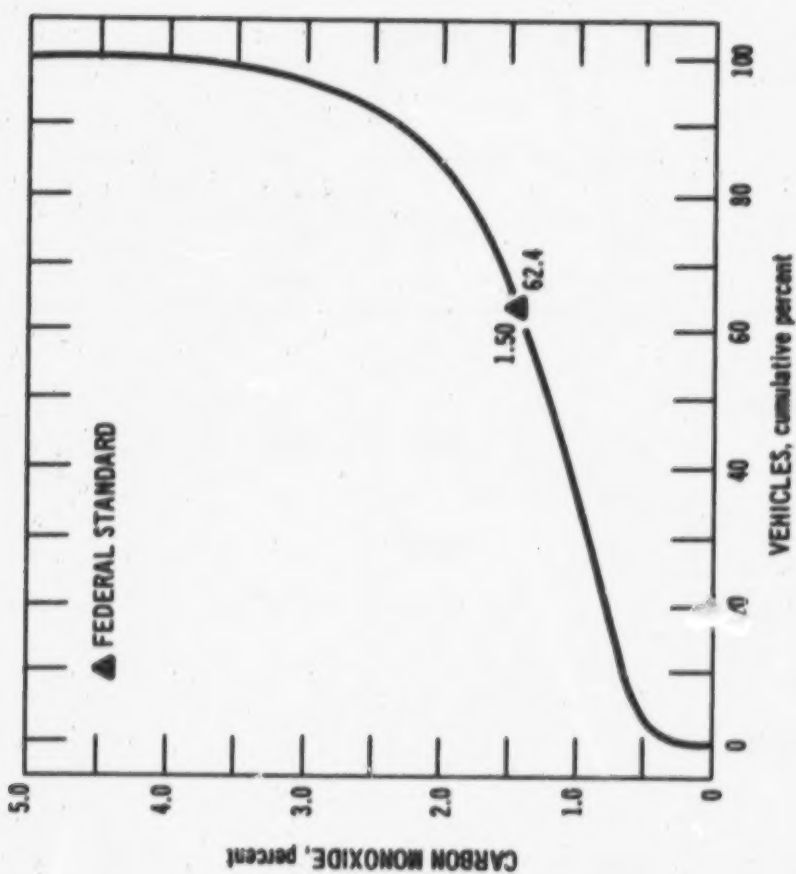


Figure 2. Carbon monoxide emissions versus cumulative percentage of domestic cars represented by test sample. (Test sample represents 65 percent of combined 1968 plus 1969 production, with percentages weighted according to production.)

Table 8. DATA SUMMARY

| Description of data                | Emissions from all cars |                   | Emissions from cars with odometer readings > 3,500 miles |                   |
|------------------------------------|-------------------------|-------------------|----------------------------------------------------------|-------------------|
|                                    | HC, ppm                 | CO, %             | HC, ppm                                                  | CO, %             |
| Cumulative % of vehicle population |                         |                   |                                                          |                   |
| 50.0                               | 216                     | 1.30              | 226                                                      | 1.20              |
| 78.0                               | 275 <sup>a</sup>        | —                 | —                                                        | —                 |
| 62.4                               | —                       | 1.50 <sup>a</sup> | —                                                        | —                 |
| 73.4                               | —                       | —                 | 275 <sup>a</sup>                                         | —                 |
| 61.2                               | —                       | —                 | —                                                        | 1.50 <sup>a</sup> |
| Production-weighted means          |                         |                   |                                                          |                   |
| Arithmetic mean                    | 236                     | 1.41              | 247                                                      | 1.45              |
| Antilog of mean log                | 223                     | 1.25              | 232                                                      | 1.29              |

<sup>a</sup>Federal standard.

## SUMMARY AND CONCLUSIONS

Results of 705 exhaust-emission tests conducted on 1968- and 1969-model-year rental vehicles by the Environmental Protection Agency's Bureau of Mobile Source Pollution Control revealed the following:

1. Exhaust emission levels varied considerably among automobiles of different manufacturers, among automobiles with different engine types, and among different engines of the same type. Most types of engines had emission levels below the limits imposed by Federal certification requirements.
2. The types of vehicles sampled in this survey represent about two-thirds of the population of 1968 and 1969 domestic automobiles. Approximately 75 percent of this population was projected to have hydrocarbon emissions that were less than the levels prescribed by the Federal certification standards, and approximately 60 percent had carbon monoxide emissions that were less than the prescribed levels, as determined by weighting test-vehicle percentages in proportion to production of that type vehicle. No statement can be made concerning compliance with standards by that portion of the population not represented in the test sample.
3. Some engines produced by Ford and Chevrolet had particularly high emission levels. More than 80 percent of the vehicles equipped with Chevrolet 307-CID engines that had been driven at least 3,500 miles produced either hydrocarbon or carbon monoxide emissions in excess of Federal certification levels. The Ford 289- and 302-CID engines also had high emission levels. These engines were used in a relatively high percentage of the vehicles produced (estimated at over 16 percent of total 1968 and 1969 domestic production, and over 24 percent of the population represented by vehicles tested in this study).
4. Vehicles in the test sample had accumulated relatively few miles, ranging from a low of 29 to a high of 27,493 miles, with an average of 7,708 miles. Past experience with the real-life vehicle population indicates that emissions increase with mileage accumulation. It is reasonable, therefore, to project that a smaller percentage of the vehicles represented in this test program will have exhaust emission levels below the Federal limits when they have been operated 50,000 miles.

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